SPECIFICATION

TITLE OF THE INVENTION

ESTIMATING METHOD OF NOx OCCLUSION AMOUNT

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates to a method for estimating an occlusion amount of NOx occluded in a NOx occlusion type reducing catalyst provided in an exhaust passage.

(2) Description of Related Art

In a diesel engine, generally, exhaust gas contains a lot of oxygen, which makes exhaust gas to be oxidizing atmosphere due to its structural characteristics (that is, exhaust gas air-fuel ratio becomes lean). Also, in the case of a gasoline engine which is capable of lean burning, exhaust gas air-fuel ratio becomes lean during lean burning. Therefore, a lean NOx catalyst has conventionally been developed so that NOx can be purified even in such an oxidizing atmosphere.

As such a lean NOx catalyst, there is a NOx occlusion type reducing catalyst (hereinafter, referred to as "a NOx occlusion catalyst" or "a catalyst" simply). A NOx occlusion catalyst is constituted to occlude NOx contained in exhaust gas in oxidizing atmosphere and to discharge the occluded NOx when CO exists under a low oxygen

concentration, whereby almost all of the NOx discharged from the NOx occlusion catalyst is reduced to harmless N_2 by reducing agent such as unburned HC, CO or the like exhausted from the engine and then exhausted to the atmosphere.

In a vehicle equipped with a NOx occlusion catalyst, so-called rich spike control is carried out in general. That is, since the continuous lean operation under lean air-fuel ratio makes a NOx occlusion catalyst to be in saturated state where no further Nox occlusion can occur, the oxygen concentration in the exhaust gas is lowered by forcibly making the air-fuel ratio rich temporarily at an appropriate timing (conducting a rich spike control) and let NOx be discharged from the NOx occlusion catalyst by supplying a reducing agent, so that the NOx occlusion catalyst is restored to the state where it can occlude NOx.

Now, in order to conduct such the rich spike control as described above, it is necessary to estimate (or detect) the NOx occlusion amount in a NOx occlusion catalyst accurately. As the estimating means of a NOx occlusion amount, there has been known, for example, the following arts.

(1) First conventional art: NOx occlusion amount estimating means using NOx sensors:

In the first conventional art, as shown in Fig.

6, NOx sensors 102 and 103 detecting the concentration of NOx are provided upstream and downstream of a catalyst 101 respectively, and an airflow sensor (not shown) which detects exhaust gas flow rate is provided in the exhaust passage.

Then, a NOx occlusion amount is estimated in an ECU 104 according to the following equation on the basis of information from the NOx sensors 102 and 103 and information from the airflow sensor.

NOx occlusion amount = ∫ exhaust gas flow rate × (NOx concentration upstream of catalyst - NOx concentration downstream of catalyst)

(2) Second conventional art: Estimating means according to a mathematical model (refer to, for example, JP-A09-72235):

In the second conventional art, a mathematical catalyst model is provided based upon a chemical phenomenon and a physical phenomenon of a catalyst such as occlusion reaction, oxidation-reduction reaction, releasing reaction and the like and a NOx occlusion amount is estimated according to an equation of the catalyst model.

In the above-described first conventional art, however, it is possible to calculate a NOx occlusion amount during lean operation, but it is impossible to detect a NOx discharge amount during rich operation (the reduced amount of occlusion amount)

by a NOx sensor. For this reason, in the case that the duration of rich operation is insufficient, there is a problem that calculation error in NOx occlusion amount occurs due to accumulation of NOx remaining in the catalyst. Further, there is a problem of cost increase because it is necessary to provide NOx sensors upstream and downstream of the catalyst respectively.

In the second conventional art, it is possible to estimate a NOx occlusion amount by only providing one NOx sensor at least downstream of a catalyst. However, since the art is mainly intended to apply to the air-fuel ratio control of a three way catalyst, the model structure is different from that of a NOx occlusion catalyst, which raises a problem that the application to a NOx occlusion catalyst is difficult. Further, even when the NOx occlusion amount is estimated by other catalyst models, characteristic value variations depending on catalyst types require modification of the model equation according to the types and a further precise modeling is additionally required in order to correspond to deterioration of the catalyst.

SUMMARY OF THE INVENTION

The present invention has been made in view of these problems, and the object thereof is to provide an estimating method of NOx occlusion amount

which is devised to estimate an NOx occlusion mount in a NOx occlusion catalyst with high accuracy through reflecting the latest state to the catalyst model at any time.

Therefore, an estimating method of NOx occlusion amount of the present invention is a method for estimating NOx occlusion amount of a NOx occlusion catalyst interposed in an exhaust passage in an engine, characterized in comprising the steps of: estimating the NOx occlusion amount by using a polynomial reflected with NOx occlusion characteristics of the NOx occlusion catalyst, and correcting each coefficient of the polynomial sequentially on the basis of NOx purification rates actually measured.

Further, it is preferable that the polynomial for obtaining the NOx occlusion amount x which is used in the estimating step includes a NOx purification rate r, an exhaust gas temperature y and exhaust gas flow velocity z, and the polynomial is a polynomial obtained by multiplying the exhaust gas temperature y and the exhaust gas flow velocity z by respective coefficients.

Further, it is preferable that the polynomial expressed by the following equation is used.

$$x = [r - (k_0 + k_2 y + k_3 z \ldots\ldots)] / (k_1 + k_4 y + \ldots\ldots)$$

Here, ki (i = 1, 2, …) are coefficients.

Furthermore, it is preferable that the correcting step comprises, in an occasion of correcting each coefficient sequentially: estimating the (N+1)-th NOx purification rate r on the basis of the N-th (N is a natural number) NOx occlusion amount x obtained from the polynomial, and correcting each coefficient such that the estimated (N + 1)-th NOx purification rate r becomes the NOx purification rate r actually measured.

In this case, it is preferable that the coefficients are corrected by using the method of least square.

Moreover, it is preferable that a NOx discharging amount in the NOx occlusion catalyst is calculated according to the following equation.

NOx discharging amount = ∫ (reducing agent concentration at catalyst inlet × reducing agent utilization rate − 0.5 × oxygen concentration in catalyst inlet) × exhaust gas flow rate

Further, it is preferable that the reducing agent utilization rate is set on the basis of the exhaust gas temperature y and the exhaust gas flow velocity z, and at the same time the characteristics of the reducing agent utilization rate are stored in a reducing agent utilization rate setting map.

In addition, it is preferable that the reducing agent utilization rate is estimated by using a

polynomial which is reflected with a NOx discharging characteristics of the NOx occlusion catalyst, and the coefficients of the polynomial are sequentially corrected on the basis of the concentration of the reducing agent.

Moreover, it is preferable that the polynomial for obtaining the reducing agent utilization rate r' includes a catalyst inlet reducing agent concentration x', the exhaust gas temperature y and the exhaust gas flow velocity z, and the polynomial is a polynomial obtained by multiplying the catalyst inlet reducing agent concentration x', the exhaust gas temperature y and the exhaust gas flow velocity z by respective coefficients.

Furthermore, it is preferable that the polynomial for obtaining the reducing agent utilization rate r' is expressed by the following equation.

$$\begin{aligned} r' &= f(x', y, z) \\ &= m_0 + m_1x' + m_2y + m_3z + m_4x'y + m_5yz + m_6zx' \\ &\quad + m_7x'^2y + m_8x'y^2 + \ldots\ldots\ldots \end{aligned}$$

Here, m_i (i = 1, 2, …) are coefficients.

Further, it is preferable that the engine is constituted such that switching can be performed between a lean operation where an exhaust gas air-fuel ratio is lean and a rich operation where the exhaust gas air-fuel ratio is rich, and the

coefficients of the polynomial are held during the rich operation, and when a difference between the NOx purification rate obtained by using the held coefficients at the starting time of the lean operation and the NOx purification rate actually measured is equal to or more than a threshold value, the NOx occlusion amount is corrected.

In addition, it is preferable that the NOx occlusion amount is corrected, when a difference between an actually measured value of the NOx purification rate r at the starting time of lean operation of the engine and an estimated value thereof is equal to or more than a threshold value.

Furthermore, it is preferable that the NOx occlusion amount is corrected based on a judge that the NOx occlusion amount calculated at the starting time of lean operation is incorrect, when a difference between the NOx purification rate estimated by the polynomial and the NOx purification rate obtained by actual measurement immediately after switching is performed from the rich operation of the engine to the lean operation thereof is equal to or more than a predetermined value.

Further, it is preferable to judge that the catalyst is abnormal, when an average value of the each coefficient in a predetermined period is deviated from a predetermined range.

As a result, according to the estimating method of a NOx occlusion amount of the present invention, anyone of the following advantages can be obtained.

First, since the NOx occlusion amount is estimated by using the polynomial reflected with NOx occlusion characteristics of a NOx occlusion catalyst and also each coefficient of the polynomial is sequentially corrected on the basis of NOx purification rates actually measured, such an advantage can be achieved that the NOx occlusion amount can be estimated with high accuracy. Further, by estimating the NOx occlusion amount accurately, an optimal rich operation control based upon the NOx occlusion amount can be performed and fuel consumption can be improved. Furthermore, even when the NOx occlusion catalyst is changed, each coefficient is updated corresponding to the characteristics of the changed catalyst. Therefore there is an advantage that it is unnecessary to modify the model equation.

Moreover, since the NOx discharging amount is calculated on the basis of the reducing agent utilization rate, the NOx discharging amount can be estimated with relatively high precision.

In addition, since the reducing agent utilization rate is estimated by using the polynomial reflected with the NOx discharging

characteristics of the catalyst and each coefficient of the polynomial is sequentially corrected on the basis of the concentration of the reducing agent, there is such an advantage that the estimation accuracy of the NOx discharging amount can be further improved.

Further, by holding the coefficient of the polynomial during rich operation and correcting the NOx occlusion amount when the difference between the estimated NOx purification rate and the actual NOx purification rate is equal to or more than the threshold value, the estimation accuracy of the NOx occlusion amount can be further improved.

Moreover, when the average value of each coefficient in the polynomial for a predetermined period is deviated from a predetermined range, the catalyst is judged abnormal. Therefore, there is an advantage that the catalyst abnormality judge can be made with high accuracy.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an illustrative block diagram for explaining an estimating method of a NOx occlusion amount according to one embodiment of the present invention;

Fig. 2 is a map for explaining an estimating method of a NOx occlusion amount according to one embodiment of the present invention, which shows

characteristics of a NOx catalyst during NOx occlusion;

Fig. 3 is a map for explaining an estimating method of a NOx occlusion amount according to one embodiment of the present invention, which shows characteristics of a NOx catalyst during NOx discharge;

Fig. 4 is a flowchart for explaining an estimating method of a NOx occlusion amount according to one embodiment of the present invention;

Fig. 5 is a flowchart for explaining an estimating method of a NOx occlusion amount according to one embodiment of the present invention;

Fig. 6 is an illustrative block diagram for explaining a conventional art.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An estimating method of a NOx occlusion amount according to one embodiment of the present invention will be explained below with reference to the drawings. Fig. 1 is an illustrative block diagram showing the whole constitution of an exhaust system of a vehicle to which the present invention is applied.

As illustrated, a NOx occlusion catalyst 1 is

interposed in an exhaust passage 2, and a NOx sensor 3 which detects NOx concentration at a catalyst outlet is provided downstream of the NOx occlusion catalyst 1.

Further, though not illustrated, an O_2 sensor, a temperature sensor, an air flow sensor (AFS), and the like are connected to the exhaust passage 2, and oxygen concentration, exhaust gas temperature and exhaust gas flow rate in the exhaust passage 2 are respectively detected by these sensors.

Furthermore, each sensor 3 is connected to an ECU 4 serving as a control unit. Here, the ECU 4 is provided with an input/output unit, a storage unit (a ROM, a RAM, a non-volatile RAM or the like), a processing unit (CPU), a timer counter and the like, and estimation of a NOx occlusion amount in the NOx occlusion catalyst 1 is performed by the ECU 4.

Further, various maps are provided in the ECU 4, where respective concentrations of NOx, CO and HC at the catalyst inlet (hereinafter, referred to as catalyst inlet [NOx], catalyst inlet [CO] and catalyst inlet [HC], respectively) are read out from the maps by utilizing, for example, the acceleration opening degree or the number of rotation of the engine as parameters. In this embodiment, these values are obtained from the maps, but these values

may be directly detected from the various sensors provided in the exhaust passage 2.

Now, the above-described second conventional art is constituted such that the characteristics themselves of the NOx occlusion catalyst are described with a mathematical expression to obtain a NOx occlusion amount, meanwhile the present invention is constituted such that a NOx occlusion amount is calculated by using a quartic linear polynomial.

That is, the polynomial as shown below in the equation (1) is stored in the ECU 4, and a NOx purification rate and a NOx occlusion percentage in the NOx occlusion catalyst 1 are calculated on the basis of the polynomial.

$$\begin{aligned} r &= f(x, y, z) \\ &= k_0 + k_1x + k_2y + k_3z + k_4xy + k_5yz + k_6zx \\ &\quad + k_7x^2y + k_8xy^2 + \ldots\ldots \qquad \ldots\ldots(1) \end{aligned}$$

In the equation (1), r is a NOx purification rate, x is a NOx occlusion percentage, y is an exhaust gas temperature, z is a SV value (or an exhaust gas flow velocity), and k_0, k_1, k_2, ... are coefficients.

Here, the NOx occlusion characteristics of the NOx occlusion catalyst 1 can be known by such as an experiment in advance, and it can be approximated with a polynomial. For example, if there are three parameters (cubic), the characteristics of the

catalyst can be represented with a curved face as shown in Fig. 2, and it can be expressed by a polynomial. Of course, since the equation (1) is quartic, the characteristics does not form such a curved face as shown in Fig. 2, but the same concept as the cubic case can be applied.

Further, each coefficient ki (i = 1, 2, …) is input with a proper value as an initial value on the basis of the characteristics preliminarily obtained from experiments or the like.

Then, the latest catalyst condition can always be represented according to the equation (1) by correcting each coefficient ki sequentially on the basis of detected values of the NOx sensor 3 downstream of the catalyst during engine operation.

Hereinafter NOx estimation means will be explained in further detail. First, the NOx purification rate r in the equation (1) can also be obtained by the following equation (2).

r = NOx concentration at catalyst outlet / NOx concentration at catalyst inlet …… (2)

Here, the NOx concentration at catalyst outlet is a value detected at the NOx sensor 3, and the NOx concentration at catalyst inlet can also be obtained from a map. Therefore, the NOx purification rate r obtained by the equation (2) can be said to be a sensor value (an actually measured

value), while the NOx purification rate r obtained by the equation (1) can be said to be an estimated value (a calculated value).

Further, actually measured data or map values are applied to the exhaust gas temperature [y] and SV value [z] in the equation (1). Thereby, the unknown value in the equation (1) is only the NOx occlusion percentage [x] now, while other values except this are known. Accordingly, the NOx occlusion percentage [x] can be obtained by the following equation (3), which is modification of equation (1).

$$x = [r - (k_0 + k_2 y + k_3 z \ldots)] / (k_1 + k_4 y + \ldots) \quad \ldots\ldots (3)$$

Then, the NOx occlusion percentage [x] obtained by the equation (3) is returned back in the equation (1) again, and it is used for calculation in the next calculation cycle. That is, in the equation (1), the purification rate r is calculated by using the NOx occlusion percentage [x] obtained the previous time, and newly detected [y] and [z].

Here, the purification rate r calculated by the equation (1) is an estimated value, but when each coefficient k_i is an accurate value, the estimated value of the purification rate r and the actually measured value obtained by the equation (2) should coincide with each other.

Therefore, in this invention, the estimated value and the actually measured value of the purification rate r are compared with each other, and when there is a difference between the two, each coefficient k_i is sequentially corrected by using the method of least square so that the estimated value coincides with the actually measured value. Then, the polynomial of the equation (1) can be modified at any time to the equation reflected with the state of the NOx occlusion catalyst 1 accurately by repeating such calculations to correct sequentially each coefficient ki.

That is, though the characteristics of the NOx occlusion catalyst 1 will vary according to its operating situation, its age deterioration or the like, the equation (1) is kept to serve as an equation representing the state of the catalyst 1 accurately by means of repetitive corrections of the coefficient ki, hence the NOx occlusion amount can be estimated with a high accuracy. Incidentally, the NOx occlusion percentage [x] obtained according to the equation (3) is an instantaneous NOx occlusion amount in the calculation cycle of the initial stage, but an accumulated value of the NOx occluded in the catalyst 1 can be obtained by returning the calculation result to the equation (1) repeatedly to calculate the purification rate r.

Thus, during lean operation where NOx is occluded, the catalyst outlet [NOx] is captured from the NOx sensor provided downstream of the catalyst and the captured value and the estimated value according to the equation (2) are compared with each other, then an accurate NOx occlusion amount can be obtained by correcting the coefficient ki by the method of least square for each comparison.

By the way, since NOx is discharged during rich operation, unless an accurate NOx discharge amount can be detected or estimated, an initial value of the NOx occlusion amount at the next lean operation cannot be calculated accurately.

Therefore, the coefficient ki is held during the rich operation and the NOx discharging amount is calculated according to the following equations (4) and (5), and the NOx occlusion amount during rich operation is calculated by subtracting the NOx discharging amount calculated according to the equations (4) and (5) from the NOx occlusion amount just before the start of the rich operation.

NOx discharging amount = $\int$ (reducing agent concentration at catalyst inlet × reducing agent utilization rate [r′] − 0.5 × catalyst inlet[O_2]) × exhaust gas flow rate …… (4)

Reducing agent utilization rate [r′] = f (y, z)…(5)

Here, a reducing agent utilization rate

setting map as shown in Fig. 3 is provided in the ECU1. The characteristics of the reducing agent utilization rate based upon the exhaust gas temperature [y] and the SV value [z] are stored in the map, so that the reducing agent utilization rate is set on the basis of the parameters [y] and [z].

Further, the catalyst inlet reducing agent concentration (catalyst inlet [CO] and catalyst inlet [HC]) can be obtained from the map utilizing the acceleration opening degree or the number of engine revolution as parameters, and other parameters can also be obtained as map values or detected values.

Therefore, when switching is preformed from the lean operation to the rich operation, each coefficient ki at the time of lean operation termination is held and the NOx occlusion amount is stored in the ECU4, and when switching is performed from the rich operation to the lean operation again, the remaining amount of NOx is calculated by subtracting the NOx discharged amount at the time of rich operation termination from the NOx occlusion amount.

Moreover, when a difference between an actually measured value and an estimated value of the NOx purification rate r at the time of lean operation start is equal to or more than a threshold

value, the NOx occlusion amount is corrected in the ECU 4. That is, when a difference between the NOx purification rate estimated according to the equation (1) and the NOx purification rate obtained according to the equation (2) immediately after switching has been performed from the rich operation to the lean operation is equal to or more than a predetermined value, judgement is made that the NOx remaining amount calculated at the starting time of lean operation (= the NOx occlusion amount at the time of the latest lean operation termination - the NOx discharged amount at the time of the rich operation termination) is incorrect, and the NOx remaining amount [x] (that is, the NOx occlusion amount at the time of lean operation start) is corrected on the basis of the equation (3).

In addition, the ECU 4 has such a function that, when the coefficient ki becomes an abnormal value due to an accidental irregularity of the catalyst 1 or the like, the ECU 4 detects such a fact and notifies it to a driver. Specifically, regarding each coefficient ki, moving averages in a predetermined continuous calculation cycle are calculated constantly and when the value of a moving average is deviated from the predetermined range set for each coefficient, an abnormality judgment is made such that deterioration or damage has

occurred in the catalyst 1. Incidentally, the predetermined range is established by adding $\pm\alpha$ (α is a constant value) to an initial value of each coefficient ki, for example.

Further, when the ECU4 judges that the catalyst 1 is abnormal, an alarming lamp on the instrument panel, for example, is turned on and the rich operation is inhibited.

Thus, inhibiting the rich operation at an abnormal occasion of the catalyst 1 can avoid an event like CO discharge in advance properly.

Since the estimating method of a NOx occlusion amount according to one embodiment of the present invention is constituted as described above, the NOx occlusion amount is estimated in the following manner.

In a lean operation, first, the actual NOx purification rate r is calculated according to the equation (2) and the exhaust gas temperature [y] and the SV value [z] are obtained from the actually measured data or the map values. Also, in the polynomial of equation (1), a suitable value obtained by experiments or the like is inputted for each coefficient ki as an initial value. Then, each value is substituted for the equation (3) obtained by modifying the equation (1) to calculate the NOx occlusion percentage [x].

Next, the NOx occlusion percentage [x] obtained according to the equation (3), the newly obtained exhaust gas temperature [y] and the SV value [z] are substituted for the equation (1) to obtain a NOx purification rate r (an estimated value). Then, the estimated NOx purification rate r and the actual NOx purification rate r newly calculated according to the equation (2) are compared with each other, and each coefficient ki is corrected by the method of least square so that the estimated NOx purification rate is coincident with the actual NOx purification rate.

Then, such calculations are performed repeatedly to update each coefficient ki at any time, which makes the equation (1) to be an expression representing an accurate state of the catalyst 1, and realizes that the NOx occlusion amount can be estimated with a high accuracy. Further, the accumulated value of the NOx occluded in the catalyst 1 can be obtained by repeated calculation of the NOx occlusion percentage [x] using the equation (3).

In addition, as NOx is discharged during a rich operation, the calculation of the NOx occlusion amount according to the equation (1) is suspended at this time and each coefficient ki is stored, meanwhile the NOx discharging amount is calculated according to the equations (4) and (5) described

above.

Then, when switching is performed from rich operation to lean operation again, the NOx remaining amount at the time of lean operation start is calculated by subtracting the NOx discharged amount at the time of rich operation termination from the NOx occlusion amount at the time of lean operation termination.

Further, when a difference between the actually measured value and the estimated value of the NOx purification rate r at the time of lean operation start is equal to or more than a threshold value, the NOx occlusion amount is corrected. Here, the correction means for the NOx occlusion amount will be explained with reference to a flowchart shown in Fig. 4. First, each coefficient k_i of the polynomial (1) is sequentially corrected during the lean operation to identify each coefficient k_i (Step S1).

Then, when it is judged that a rich operation has started (Step S2), each coefficient ki is held (Step S3). Thereafter, when the rich operation is terminated (Step S4), an actually measured value and an estimated value of the NOx purification rate are compared with each other and judgement is made whether or not a difference between the both is equal to or more than the threshold value (Step S5).

When the difference between the actually measured value and the estimated value of the NOx purification rate is less than the threshold value, returning back to Step 1 again, and updating each coefficient k_i in the lean operation is continued, while the difference is equal to or more than the threshold value, the NOx occlusion amount is corrected to a value calculated according to the equation (3) (Step S6) and the flow returns.

Thus, the estimation accuracy of the NOx occlusion amount can further be enhanced by correcting means of the NOx occlusion amount in this manner.

On the other hand, when deterioration or irregularity of the catalyst 1 is judged, the judgement is notified to the driver by turning on the alarm lamp in the instrument panel and the rich operation is inhibited. This procedure will be explained according to a flowchart shown in Fig. 5. Each coefficient k_i of the polynomial (1) is sequentially corrected and identified (Step S11), and the moving average of each coefficient k_i for a fixed period is then calculated (Step S12).

Next, judgement is made about whether or not the moving average of each coefficient k_i calculated falls within a predetermined range (Step S13). When the moving average of any coefficient is within a

predetermined range, the flow returns back to Step S2 again. However, when at least one of the moving averages of the coefficients k_i is out of the corresponding predetermined range, judgement is made that abnormality has occurred in the catalyst 1 to give an alarm (Step S14) and inhibit the rich operation (Step S15).

As described above in detail, according to the estimating method of NOx occlusion amount according to the embodiment of the present invention, since the NOx occlusion amount is estimated by using the polynomial reflected with the NOx occlusion characteristics of the NOx occlusion catalyst 1 and each coefficient k_i of the polynomial is sequentially corrected on the basis of the actually measured NOx purification rates, there is an advantage that the polynomial which is modeled consistently with the latest catalyst state can be obtained and the NOx occlusion amount can be estimated with high accuracy. Further, by estimating the NOx occlusion amount accurately, the optimal rich operation control can be conducted on the basis of the NOx occlusion amount and fuel consumption can be improved.

Further, even if the NOx occlusion catalyst 1 is changed, since updating to each coefficient ki corresponding to the characteristics of the

changed catalyst 1 is conducted, there is such an advantage that modification of the model equation is not required. On the other hand, when a mathematical model equation is applied as the conventional art, there occurs such a problem that works (fitting) for identifying coefficients corresponding to the characteristics of each catalyst is needed, which requires tremendous labor. In the present invention, however, the NOx occlusion amount can be estimated accurately without conducting such fitting works.

Since the NOx discharging amount is calculated on the basis of the reducing agent utilization rate, the NOx discharged amount can be estimated with a relatively high precision.

Furthermore, the coefficient k_i of the polynomial is held during rich operation, and when the difference between the NOx purification rate estimated by using the coefficient held at the time of lean operation start and the actually measured NOx purification rate is equal to or more than a threshold value, the NOx occlusion amount is corrected, therefore the estimation precision of the NOx occlusion amount can further be enhanced.

When the average value of each coefficient k_i for a predetermined period is deviated from a predetermined range, it is judged that the catalyst

1 is abnormal, therefore the abnormality of the catalyst 1 can be judged with a high precision. Further, since an alarm is sent out to the driver at the time of such abnormality judgement, the driver can recognize the abnormality of the catalyst 1 immediately, which promotes the driver to exchange catalysts 1 early. Further, since the rich operation is inhibited in case of such an abnormality of catalyst 1, the event that CO is exhausted as it is can be avoided.

Incidentally, the estimating method of a NOx occlusion amount of the present invention is not limited to the above-described embodiments, but it may be modified in various ways within the range not deviated from the scope and spirit of the invention. For example, the discharging amount of NOx can be obtained from an approach similar to the estimating method of a NOx occlusion amount.

Namely, though the reducing agent utilization rate [r'] used for calculating the NOx discharged amount is obtained from the reducing agent utilization rate setting map shown in Fig. 3, it may be obtained according to a polynomial of catalyst inlet reducing agent concentration [x'], exhaust gas temperature [y] and SV value [z] as shown in the following equation (6).

$r' = f(x', y, z)$

$$= m_0 + m_1x' + m_2y + m_3z + m_4x'y + m_5yz + m_6zx' + m_7x'^2y + m_8x'y^2 + \ldots\ldots \quad \ldots\ldots\ldots (6)$$

Here, m_i ($i = 1, 2, \ldots$) are coefficients. Further, the equation (6) is a polynomial reflected with NOx discharging characteristics of the NOx occlusion catalyst, where each coefficient m_i is inputted with a proper initial value obtained from experiments or the like as an initial value similarly to the equation (1).

In this case, additionally, a sensor (a CO sensor) for detecting a reducing agent (specifically CO) concentration is provided at least in the exhaust passage 2, and the reducing agent utilization rate r' is obtained by sequentially updating each coefficient m_i from actually measured values of the reducing agent concentration [x'] obtained from the CO sensor and estimated values of the reducing agent concentration [x'] obtained according to the equation (6), and then the NOx discharged amount can be obtained by substituting the value thus obtained for the above-described equation (4).

The estimation precision of the NOx discharged amount can be improved by obtaining the NOx discharged amount in this manner.